

Can Science ‘explain’ Consciousness ?

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Consciousness is the process by which one attributes ‘meaning’ to the world. Considering Føllesdal’s definition of ‘meaning’ as the joint product of all ‘evidence’ that is available to those who ‘communicate’, we conclude that science can, not only reduce all the *evidence* to a Basic Entity (we call BE), but also can ‘explain’ consciousness once a suitable definition for *communication* is found that exploits the quantum superposition principle to incorporate the fuzziness of our experience. Consciousness may be beyond ‘computability’, but it is not beyond ‘communicability’.

I. INTRODUCTION

Among all the human endeavours, science can be considered to be the most powerful for the maximum power it endows us to manipulate the nature through an understanding of our position in it. This understanding is gained when a set of careful observations based on tangible perceptions, acquired by sensory organs and/or their extensions, is submitted to the logical analysis of human intellect as well as to the intuitive power of imagination to yield the abstract fundamental laws of nature that are not self-evident at the gross level of phenomenal existence. There exists a unity in nature at the level of laws that corresponds to the manifest diversity at the level of phenomena.

Can consciousness be understood in this sense by an appropriate use of the methodology of science ? The most difficult problem related to consciousness is perhaps, ‘how to define it ?’. Consciousness has remained a unitary subjective experience, its various ‘components’ being reflective (the recognition by the thinking subject of its own actions and mental states), perceptual (the state or faculty of being mentally aware of external environment) and a free will (volition). But how these components are integrated to provide the unique experience called ‘consciousness’, familiar to all of us, remains a mystery. Does it lie at the level of ‘perceptions’ or at the level of ‘laws’ ? *Can it be reduced to some basic ‘substance’ or ‘phenomenon’ ? Can it be manipulated in a controlled way ? Is there a need for a change of either the methodology or the paradigm of science to answer the above questions ?* In this article, I make a modest attempt to answer these questions, albeit in a speculative manner.

II. CAN CONSCIOUSNESS BE REDUCED FURTHER ?

Most of the successes of science over the past five hundred years or so can be attributed to the great emphasis it lays on the ‘reductionist paradigm’. Following this approach, can consciousness be reduced either to ‘substance’ or ‘phenomena’ in the sense that by understanding which one can understand consciousness ?

A. Physical Substratum

The attempts to reduce consciousness to a physical basis have been made in the following ways by trying to understand the mechanism and functioning of the human brain in various different contexts.

• Physics

The basic substratum of physical reality is the ‘state’ of the system and the whole job of physics can be put into a single question : ‘given the initial state, how to predict its evolution at a later time ?’. In classical world, the state and its evolution can be reduced to events and their spatio-temporal correlations. Consciousness has no *direct* role to play in this process of reduction, although it is responsible to find an ‘objective meaning’ in such a reduction.

But the situation is quite different in the quantum world as all relevant physical information about a system is contained in its wavefunction (or equivalently in its state vector), which is not physical in the sense of being directly measurable. Consciousness plays no role in the deterministic and unitary Schrödinger evolution (i.e. the U-process of Penrose [1]) that the ‘unphysical’ wavefunction undergoes.

To extract any physical information from the wavefunction one has to use the Born-Dirac rule and thus probability enters in a new way into the quantum mechanical description despite the strictly deterministic nature of evolution

of the wavefunction. The measurement process forces the system to choose an 'actuality' from all 'possibilities' and thus leads to a non-unitary collapse of the general wavefunction to an eigenstate (i.e. the **R**-process of Penrose [1]) of the concerned observable. The dynamics of this **R**-process is not known and it is here some authors like Wigner have brought in the consciousness of the observer to cause the collapse of the wavefunction. But instead of explaining the consciousness, this approach uses consciousness for the sake of Quantum Mechanics which needs the **R**-process along with the **U**-process to yield all its spectacular successes.

The **R**-process is necessarily *non-local* and is governed by an irreducible element of chance, which means that the theory is not naturalistic: the dynamics is controlled in part by something that is not a part of the physical universe. Stapp [2] has given a quantum mechanical model of the brain dynamics in which this quantum selection process is a causal process governed not by pure chance but rather by a mathematically specified non-local physical process identifiable as the *conscious process*. It was reported [3] that attempts have been made to explain consciousness by relating it to the 'quantum events', but any such attempt is bound to be futile as the concept of 'quantum event' in itself is ill-defined !

Keeping in view the fundamental role that the quantum vacuum plays in formulating the quantum field theories of all four known basic interactions of nature spreading over a period from the big-bang to the present, it has been suggested [4] that if at all consciousness be reduced to anything 'fundamental' that should be the 'quantum vacuum' in itself. But in such an approach the following questions arise: 1) If consciousness has its origin in the quantum vacuum that gives rise to all fundamental particles as well as the force fields, then why is it that only living things possess consciousness ?, 2) What is the relation between the quantum vacuum that gives rise to consciousness and the space-time continuum that confines all our perceptions through which consciousness manifests itself ?, 3) Should one attribute consciousness only to systems consisting of 'real' particles or also to systems containing 'virtual' particles ? Despite these questions, the idea of tracing the origin of 'consciousness' to 'substantial nothingness' appears quite promising because the properties of 'quantum vacuum' may ultimately lead us to an understanding of the dynamics of the **R**-process and thus to a physical comprehension of consciousness.

One of the properties that distinguishes living systems from the non-living systems is their ability of self-organisation and complexity. Since life is a necessary condition for possessing consciousness, can one attribute consciousness to a 'degree of complexity' in the sense that various degrees of consciousness can be caused by different levels of complexity? Can one give a suitable quantitative definition of consciousness in terms of 'entropy' that describes the 'degree of self-organisation or complexity' of a system ? What is the role of non-linearity and non-equilibrium thermodynamics in such a definition of consciousness ? In this holistic view of consciousness what is the role played by the phenomenon of *quantum non-locality*, first envisaged in EPR paper [5] and subsequently confirmed experimentally [6] by Aspect et. al ? What is the role of irreversibility and dissipation in this holistic view ?

• Neuro-biology

On the basis of the vast amount of information available on the structure and the modes of communication (neuro-transmitters, neuro-modulators, neuro-hormones) of the neuron, neuroscience has empirically found [7] the neural basis of several attributes of consciousness. With the help of modern scanning techniques and by direct manipulations of the brain, neuro-biologists have found out that various human activities (both physical and mental) and perceptions can be mapped into almost unique regions of the brain. Awareness, being intrinsic to neural activity, arises in higher level processing centers and requires integration of activity over time at the neuronal level. But there exists no particular region that can be attributed to have given rise to consciousness. Consciousness appears to be a collective phenomena where the 'whole' is much more than the sum of parts ! *Is each neuron having the 'whole of consciousness' within it, although it does work towards a particular attribute of consciousness at a time ?*

Can this paradigm of finding neural correlates of the attributes of consciousness be fruitful in demystifying consciousness ? Certainly not ! As it was aptly concluded [8] the currently prevalent reductionist approaches are unlikely to reveal the basis of such holistic phenomenon as consciousness. There have been holistic attempts [9,1] to understand consciousness in terms of collective quantum effects arising in cytoskeletons and microtubules; minute substructures lying deep within the brain's neurons. The effect of *general anaesthetics* like chloroform (CHCl_3), isoflurane ($\text{CHF}_2\text{OCHClCF}_3$) etc. in switching off the consciousness, not only in higher animals such as mammals or birds but also in paramecium, amoeba, or even green slime mould has been advocated [10] to be providing a direct evidence that the phenomenon of consciousness is related to the action of the cytoskeleton and to microtubules. But all the implications of 'quantum coherence' regarding consciousness in such approach can only be unfolded after we achieve a better understanding of 'quantum reality', which still lies ahead of the present-day physics.

• Artificial Intelligence

Can machines be intelligent ? Within the restricted definition of 'artificial intelligence', the neural network approach has been the most promising one. But the possibility of realising a machine capable of artificial intelligence based

on this approach is constrained at present [11] by the limitations of 'silicon technology' for integrating the desired astronomical number of 'neuron-equivalents' into a reasonable compact space. Even though we might achieve such a feat in the foreseeable future by using chemical memories, it is not quite clear whether such artificially intelligent machines can be capable of 'artificial consciousness'. Because one lacks at present a suitable working definition of 'consciousness' within the frame-work of studies involving artificial intelligence.

Invoking Gödel's incompleteness theorem, Penrose has argued [1] that the technology of electronic computer-controlled robots will not provide a way to the artificial construction of an actually intelligent machine—in the sense of a machine that 'understands' what it is doing and can act upon that understanding. He maintains that human understanding (hence consciousness) lies beyond formal arguments and beyond computability i.e. in the Turing-machine-accessible sense.

Assuming the inherent ability of quantum mechanics to incorporate consciousness, can one expect any improvement in the above situation by considering 'computation' to be a physical process that is governed by the rules of quantum mechanics rather than that of classical physics ? In 'Quantum computation' [12] the classical notion of a Turing machine is extended to a corresponding quantum one that takes into account *the quantum superposition principle*. In 'standard' quantum computation, the usual rules of quantum theory are adopted, in which the system evolves according to the **U**-process for essentially the entire operation, but the **R**-process becomes relevant mainly only at the end of the operation, when the system is 'measured' in order to ascertain either the termination or the result of the computation.

Although the superiority of the quantum computation over classical computation in the sense of complexity theory have been shown [13], Penrose insists that it is still a 'computational' process since **U**-process is a computable operation and **R**-process is purely probabilistic procedure. What can be achieved in principle by a quantum computer could also be achieved, in principle, by a suitable Turing-machine-with-randomiser. Thus he concludes that even a quantum computer would not be able to perform the operations required for human conscious understanding. But we think that such a view is limited because 'computation' as a process need not be confined to a Turing-machine-accessible sense and in such situations one has to explore the power of quantum computation in understanding consciousness.

We conclude from the above discussions that the basic physical substrata to which consciousness may be reduced are 'neuron', 'event' and 'bit' at the classical level, whereas at the quantum level they are 'microtuble', 'wavefunction' and 'qubit'; depending on whether the studies are done in neuro-biology, physics and computer science respectively. Can there be a common platform for these trio of substrata ?

We believe the answer to be in affirmative and the first hint regarding this comes from Wheeler's [14] remarkable idea: "**it from bit** i.e. every **it** – every particle, every field of force, even the spacetime continuum itself – derives its function, its meaning, its very existence entirely – even if in some contexts indirectly – from the apparatus-elicited answers to yes or no questions, binary choices, **bits**". This view of the world refers not to an object, but to a vision of a world derived from pure logic and mathematics in the sense that an *immaterial* source and explanation lies at the bottom of every item of the physical world. In a recent report [15] the remarkable extent of embodiment of this vision in modern physics has been discussed alongwith the possible difficulties faced by such a scheme. But can this scheme explain consciousness by reducing it to **bits** ? Perhaps not unless it undergoes some modification. Why ?

Because consciousness involves an awareness of an endless mosaic of qualitatively different things –such as the colour of a rose, the fragrance of a perfume, the music of a piano, the tactile sense of objects, the power of abstraction, the intuitive feeling for time and space, emotional states like love and hate, the ability to put oneself in other's position, the ability to wonder, the power to wonder at one's wondering etc. It is almost impossible to reduce them all to the 0-or-1 sharpness of the definition of 'bits'. A major part of human experience and consciousness is *fuzzy* and hence can not be reduced to yes or no type situations. Hence we believe that 'bit' has to be modified to incorporate this fuzziness of the world. Perhaps the quantum superposition inherent to a 'qubit' can help. Can one then reduce the consciousness to a consistent theory of 'quantum information' based on qubits ? Quite unlikely, till our knowledge of 'quantum reality' and the 'emergence of classicality from it' becomes more clear.

The major hurdles to be cleared are (1) **Observer or Participant** ? (In such equipment-evoked, quantum-information-theoretic approach, the inseparability of the observer from the observed will bring in the quantum measurement problem either in the form of dynamics of the **R**-process or in the emergence of classicality of the world from a quantum substratum. We first need the solutions to these long-standing problems before attempting to reduce the 'fuzzy' world of consciousness to 'qubits' !); (2) **Communication** ? (Even if we get the solutions to the above problems that enable us to reduce the 'attributes of consciousness' to 'qubits', still then the 'dynamics of the process that gives rise to consciousness' will be beyond 'quantum information' as it will require a suitable definition of 'communication' in the sense expressed by Føllesdal [16] " Meaning is the joint product of all evidence that is available to those who communicate". Consciousness helps us to find a 'meaning' or 'understanding' and will depend upon 'communication'. Although all 'evidence' can be reduced to qubits, 'communication' as an exchange of qubits has to be well-defined. Why do we say that a stone or a tree is

unconscious ? Is it because we do not know how to 'communicate' with them ? Can one define 'communication' in physical terms beyond any verbal or non-verbal language ? Where does one look for a suitable definition of 'communication' ? Maybe one has to define 'communication' at the 'substantial nothingness' level of quantum vacuum.); (3) **Time's Arrow** ? (How important is the role of memory in 'possessing consciousness' ? Would our consciousness be altered if the world we experience were reversible with respect to time ? Can our consciousness ever find out why it is not possible to influence the past ?).

Hence we conclude that although consciousness may be beyond 'computability', it is not beyond 'quantum communicability' once a suitable definition for 'communication' is found that exploits the quantum superposition principle to incorporate the fuzziness of our experience. Few questions arise: 1) how to modify the qubit ?, 2) can a suitable definition of 'communication', based on immaterial entity like 'qubit' or 'modified qubit', take care of non-physical experience like dream or thoughts ? We assume, being optimistic, that a suitable modification of 'qubit' is possible that will surpass the hurdles of communicability, dynamics of **R**-process and irreversibility. For the lack of a better word we will henceforth call such a modified qubit as 'Basic Entity' (BE).

B. Non-Physical Substratum

Unlike our sensory perceptions related to physical 'substance' and 'phenomena' there exists a plethora of human experiences like dreams, thoughts and lack of any experience during sleep which are believed to be non-physical in the sense that they cannot be reduced to anything basic within the confinement of space-time and causality. For example one cannot ascribe either spatiality or causality to human thoughts, dreams etc. Does one need a frame-work that transcends spatio-temporality to incorporate such non-physical 'events' ? Or can one explain them by using BE ? The following views can be taken depending on one's belief:

- **Modified BE [M(BE)]**

What could be the basic substratum of these non-physical entities ? Could they be understood in terms of any suitably modified physical substratum ? At the classical level one might think of reducing them to 'events' which, unlike the physical events, do not have any reference to spatiality. Attempts [17] have been made to understand the non-physical entities like thoughts and dreams in terms of temporal events and correlation between them. Although such an approach may yield the kinematics of these non-physical entities, it is not clear how their dynamics i.e. evolution etc. can be understood in terms of temporal component alone without any external spatial input, when in the first place they have arose from perceptions that are meaningful only in the context of spatio-temporality ?! Secondly, it is not clear why the 'mental events' constructed after dropping the spatiality should require new set of laws that are different from the usual physical laws.

At the quantum level one might try to have a suitable modification of the wavefunction to incorporate these non-physical entities. One may make the wavefunction depend on extra parameters [18], either physical or non-physical, to give it the extra degrees of freedom to mathematically include more information. But such a wavefunction bound to have severe problems at the level of interpretation. For example, if one includes an extra parameter called 'meditation' as a new degree of freedom apart from the usual ones, then how will one interpret squared modulus of the wavefunction ? It will be certainly too crude to extend the Born rule to conclude that the squared modulus in this case will give the probability of finding a particle having certain meditation value ! Hence this kind of modification will not be of much help except for the apparent satisfaction of being able to write an eigenvalue equation for dreams or emotions ! This approach is certainly not capable of telling how the wavefunction is related to consciousness, let alone a mathematical equation for the evolution of consciousness !

If one accepts consciousness as a phenomenon that arises out of execution of processes then any suggested [19] new physical basis can be shown to be redundant. As we have concluded earlier, all such possible processes and their execution can be reduced to BE and spatio-temporal correlations among BE using a suitable definition of communication.

Hence to incorporate non-physical entities as some kind of information one has to modify the BE in a subtle way. Schematically $M(BE) = BE \otimes X$, where \otimes stands for a yet unknown operation and X stands for fundamental substratum of non-physical information. X has to be different from BE; otherwise it could be reducible to BE and then there will be no spatio-temporal distinction between physical and non-physical information. But, how to find out what is X ? Is it evident that the laws for $M(BE)$ will be different from that for BE ?

- **Give up BE**

One could believe that it is the 'Qualia' that constitutes consciousness and hence consciousness has to be understood at a phenomenological level without dissecting it into BE or $M(BE)$. One would note that consciousness mainly consists

of three phenomenological processes that can be roughly put as retentive, reflective and creative. But keeping the tremendous progress of our physical sciences and their utility to neuro-sciences in view, it is not unreasonable to expect that all these three phenomenological processes, involving both human as well as animal [20] can be understood oneday in terms of M(BE).

- **Platonic BE**

It has been suggested [21] that consciousness could be like mathematics in the sense that although it is needed to comprehend the physical reality, in itself it is not 'real'.

The 'reality' of mathematics is a controversial issue that brings in the old debate between the realists and the constructivists whether a mathematical truth is 'a discovery' or 'an invention' of the human mind ? *Should one consider the physical laws based on mathematical truth as real or not ?!* The realist's stand of attributing a Platonic existence to the mathematical truth is a matter of pure faith unless one tries to get the guidance from the knowledge of the physical world. It is doubtful whether our knowledge of physical sciences provides support for the realist's view if one considers the challenge to 'realism' in physical sciences by the quantum world-view, which has been substantiated in recent past by experiments [6] that violate Bell's inequalities.

Even if one accepts the Platonic world of mathematical forms, this no way makes consciousness non-existent or unreal. Rather the very fact that truth of such a platonic world of mathematics yields to the human understanding as much as that of a physical world makes consciousness all the more profound in its existence.

III. CAN CONSCIOUSNESS BE MANIPULATED ?

Can consciousness be manipulated in a controlled manner ? Experience tells us how difficult it is to control the thoughts and how improbable it is to control the dreams. We discuss below few methods prescribed by western psycho-analysis and oriental philosophies regarding the manipulation of consciousness. Is there a lesson for modern science to learn from these methods ?

A. Self

The subject of 'self' is usually considered to belong to an 'internal space' in contrast to the external space where we deal with others. We will consider the following two cases here:

- **Auto-suggestions**

There have been evidences that by auto-suggestions one can control one's feelings like pain and pleasure. Can one cure oneself of diseases of physical origin by auto-suggestions ? This requires further investigations.

- **Yoga and other oriental methods**

The eight-fold (*asthanga*) Yoga of Patanjali is perhaps the most ancient method prescribed [22] to control one's thought and to direct it in a controlled manner. But it requires certain control over body and emotions before one aspires to gain control over mind. In particular it lays great stress on 'breath control' (*pranayama*) as a means to relax the body and to still the mind. In its later stages it provides systematic methods to acquire concentration (*dhyan*) and to prolong concentration on an object or a thought (*dharna*).

After this attainment one can reach a stage where one's awareness of self and the surrounding is at its best. Then in its last stage, Yoga prescribes one's acute awareness to be decontextualized [23] from all perceptions limited by spatio-temporality and thus to reach a pinnacle called (*samadhi*) where one attains an understanding of everything and has no doubts. *In this sense the Yogic philosophy believes that pure consciousness transcends all perceptions and awareness.* It is difficult to understand this on the basis of day to day experience. Why does one need to sharpen one's awareness to its extreme if one is finally going to abandon its use ? How does abandoning one's sharpened awareness help in attaining a realisation that transcends spatio-temporality? Can any one realise anything that is beyond the space, time and causality ? What is the purpose of such a consciousness that lies beyond the confinement of space and time ?

B. Non-Self

The Non-Self belongs to an external world consisting of others, both living and non-living. In the following we discuss whether one can direct one's consciousness towards others such that one can affect their behaviour.

- **Hypnosis, ESP etc...**

It is a well-known fact that it is possible to hypnotise a person and then to make contact with his/her sub-conscious mind. Where does this sub-conscious lie ? What is its relation to the conscious mind ? The efficacy of the method of hypnosis in curing people of deep-rooted psychological problems tells us that we are yet to understand the dynamics of the human brain fully.

The field of Para-Psychology deals with 'phenomena' like Extra Sensory Perception (ESP) and telepathy etc. where one can direct one's consciousness to gain insight into future or to influence others mind. It is not possible to explain [23] these on the basis of the known laws of the world. It has been claimed that under hypnosis a subject could vividly recollect incidents from the previous lives including near-death and death experiences which is independent of spatio-temporality. Then, it is not clear, why most of these experiences are related to past ? *If these phenomena are truly independent of space and time, then studies should be made to find out if anybody under hypnosis can predict his/her own death, an event that can be easily verifiable in due course of time, unlike the recollections of past-life !*

- **PK, FieldREG etc.**

Can mind influence matter belonging to outside of the body ? The studies dubbed as Psycho-Kinesis (PK) have been conducted to investigate the 'suspect' interaction of the human mind with various material objects such as cards, dice, simple pendulum etc. An excellent historical overview of such studies leading upto the modern era is available as a review paper, titled " The Persistent Paradox of Psychic Phenomena: An Engineering Perspective", by Robert Jahn of Princeton University published in Proc. IEEE (Feb. 1982).

The Princeton Engineering Anomalies Research (PEAR) programme of the Department of Applied Sciences and Engineering, Princeton University, has recently developed and patented a 'Field REG' (Field Random Event Generator) device which is basically a portable notebook computer with a built-in truly random number generator (based on a microelectronic device such as a shot noise resistor or a solid-state diode) and requisite software for on-line data processing and display, specifically tailored for conducting 'mind-machine interaction' studies.

After performing large number of systematic experiments over the last two decades, the PEAR group has reported [24] the existence of such a consciousness related mind-machine interaction in the case of 'truly random devices'. They attribute it to a 'Consciousness Field Effect'. They have also reported that deterministic random number sequences such as those generated by mathematical algorithm or pseudo-random generators do not show any consciousness related anomalous behaviour. Another curious finding is that 'intense emotional resonance' generates the effect whereas 'intense intellectual resonance' does not ! *It is also not clear what is the strength of the 'consciousness field' in comparison to all the four known basic force fields of nature.*

One should not reject outright any phenomenon that cannot be explained by the known basic laws of nature. Because each such phenomenon holds the key to extend the boundary of our knowledge further. But before accepting these effects one should filter them through the rigours of scientific methodology. In particular, the following questions can be asked:

- Why are these events rare and not *repeatable* ?
- How does one make sure that these effects are not manifestations of yet *unknown* facets of the *known* forces ?
- Why is it necessary to have *truly random* processes ? How does one make sure that these are not merely statistical artifacts ?

If the above effects survive the scrutiny of the above questions (or similar ones) then they will open up the doors to a new world not yet known to science. In such a case how does one accomodate them within the existing framework of scientific methods ? If these effects are confirmed beyond doubt, then one has to explore the possibility that at the fundamental level of nature, the laws are either different from the known physical laws or there is a need to complement the known physical laws with a set of non-physical laws ! In such a situation, these 'suspect' phenomena might provide us with the valuable clue for modifying BE to get M(BE) that is the basis of everything including both physical and mental !

IV. IS THERE A NEED FOR A CHANGE OF PARADIGM ?

Although reductionist approach can provide us with valuable clues regarding the attributes of consciousness, it is the holistic approach that can only explain consciousness. But the dualism of Descarte [25] that treats physical and mental processes in a mutually exclusive manner will not suffice for understanding consciousness unless it makes an appropriate use of complementarity for mental and physical events which is analogous to the complementarity evident in the quantum world.

V. CONCLUSION

Where does the brain end and the mind begin ? Brain is the physical means to acquire and to retain the information for the mind to process them to find a 'meaning' or a 'structure' which we call 'understanding' that is attributed to consciousness. Whereas attributes of consciousness can be reduced to BE [or to M(BE)], the holistic process of consciousness can only be understood in terms of 'quantum communication', where 'communication' has an appropriate meaning. Maybe one has to look for such a suitable definition of communication at the level of 'quantum vacuum'.

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- [1] Penrose, R., *Emperor's New Mind and Shadows of the Mind*, Vintage Editions, (1998).
- [2] Stapp, H. P., *Chance, Choice, and Consciousness: The Role of Mind in the Quantum Brain*, quant-ph/9511029 (electronic archive at LANL).
- [3] Nair, Ranjit, *Consciousness and the Quantum* in this conference.
- [4] Sreekantan, B. V., *Scientific Explanations and Consciousness* in this conference.
- [5] Einstein, A., Podolsky, P., and Rosen, N., (1935), *Can quantum-mechanical description of physical reality be considered complete ?*, Phys. Rev. **47**, 777-80.
- [6] Aspect, A., Grangier, P., and Roger, G. (1982), *Experimental realization of Einstein-Podolsky-Rosen-Bohm Gedankenexperiment: a new violation of Bell's inequalities*, Phys. Rev. Lett., **48**, 91-4.
- [7] Rao, Shobhini, *Neural Correlates and Consciousness* in this conference.
- [8] Tondon, P. N., *Exploring Consciousness-Neurobiological Approaches* in this conference.
- [9] Hameroff, S. R., (1987) *Ultimate computing, Biomolecular consciousness and nano-technology*, North-Holland, Amsterdam.
- [10] Hameroff, S. R. and Watt, R. C. (1983), *Do anesthetics act by altering electron mobility ?*, Anesth. Analg., **62**, 936-40.
- [11] Vidyasagar, M., *Artificial Intelligence* in this conference.
- [12] Deutsch, D. (1985), *Quantum theory, the Church-Turing principle and the universal quantum computer* in Proc. Roy. Soc. (London), **A 400**, 97-117; Feynman R. P., (1986), *Quantum mechanical Computers*, Found. of Phys., **16(6)**, 507-31.
- [13] Deutsch, D. and Jozsa, R. (1992), *Rapid solution of problems by quantum computation*, Proc. Roy. Soc. (London), **A 439**, 553-8.
- [14] Wheeler, J. A., (1989), *Information, Physics, Quantum: the Search for the Links*, Proc. 3rd Int. symp. Foundations of Quantum Mechanics, Tokyo, pp. 354-368.
- [15] Wilczek, F., (1999), *Getting its from bits*, Nature **397**, 303-6.
- [16] D. Føllesdal, (1975), *Meaning and Experience in 'Mind and Language'*, ed. S. Guttenplan (Clarendon, Oxford), pp. 25-44.
- [17] Singh, N., *Fundamental Laws of mental events* in this conference.
- [18] Kaushal, R. S., *Plurality of Consciousness in Vedantic Philosophy and its role in Scientific Observations* in this conference.
- [19] Singh, R. K., *A Physical Basis of Consciousness* in this conference.
- [20] Sinha, A., *Almost Minds? The Search for Animal Consciousness* in this conference.
- [21] Sarukkai, S., *Reality and Consciousness* in this conference.
- [22] Iyengar, B. K. S., *Light on Yoga*, Unwin Publishers, London.
- [23] Krishna Rao P. V., *Yoga and Transformation of Consciousness* in this conference.
- [24] Srinivasan, M., *Experimental studies on interaction of human consciousness with physical systems* in this conference.
- [25] Narasimhan, M. G., *The Emergence of Cartesian Paradigm and Its Impacts on Later Developments* in this conference.